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MONITORING OF POLLUTANT CONCENTRATIONS IN AN UNDERGROUND URANIUM MINING PROJECT USING AERMOD

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ABSTRACT

The uranium mine at Tummalapalle is one among very few mines in India that supplies fuel to nuclear power plants. Investigations made by Atomic Minerals Directorate of Exploration and Research (AMD), India established the existence of abundant low grade uranium ore in Tummalapalle area of Kadapa district, AP, India and stressed it as feasible source for commercial extraction. As the extraction process involves dispersion of particulate matter into the atmosphere, it is essential to make an assessment of pollutant dispersion during mining which involves extracting larger quantities. To this end an air quality assessment was undertaken to evaluate the concentrations of PM 10, Uranium, Sox, NOx in and around Tummalapalle mine with the help of High volume air samplers for a period of 2011 January to 2011 December. AERMOD View-Air dispersion model (modified Gaussian plume dispersion package) was used to mathematically predict the air quality. The obtained concentrations and dispersions from AERMOD VIEW and MATLAB were compared with the monitored values at different locations and observed a quite agreement among three. Small deviations are noticed and these may be because of inbuilt confines of the models and uncertainties in the source emission characteristics. A detailed overview of basic mathematics behind atmospheric dispersion modeling software suggests AERMOD is the best modeling tool for the medium range atmospheric modeling where as MATLAB could only perform well for the short range modeling.

KEYWORDS: Air Pollution, Modified Gaussian Model, Mathematical Equations, Dispersion Model, AERMOD, MATLAB and CPCB

INTRODUCTION

Uranium is the basic energy mineral used at present in nuclear power plants. In India the first uranium mining and ore processing operations commenced in the mid-1960s at Jaduguda in the eastern part of country and later on it continued to many places like Tummalapalle, Lambapur, Peddaghattu etc, as Significant uranium deposits are known to exist at these places to meet the requirement. The extraction of ore involves different industrial activities: mining, transportation and reprocessing of uranium ore. The Tummalapalle Project includes 36 km ore belt of Vempalle deposits. All ore extracted during mining at the two sites would be processed through a mill on the site Tummalapalle has a uranium extraction and ore production facility along with power generation plant that produce conventional air pollutants besides Trucks and vehicle exhausts on-site. This study was undertaken primarily to evaluate possible health impacts of PM 10 and Uranium, as the study progressed; we realized that it presented a valuable opportunity to analyze the mathematical aspects and the

predictive capability of the model. There was no sufficient data available to prepare the emission inventory, for the emissions released from underground Uranium mine operations. Default emission factors mentioned in USEPA's National Pollution Inventory (NPI) for PM10 for mineral mining were used to calculate the emission rates.

Receptor locations were taken in the nested grid form and high volume air samplers locations were used as discrete receptors in a Cartesian coordinate system. Site location involved elevated terrain. In order to achieve the aim of this study, the pollutant distribution inside the study area was assumed as a function of meteorological data, background pollutant concentration, on site traffic intensity and mine pollution emissions. MATLAB Mathematical algorithms were used to generate repetitious solutions for the complicated equations which describe the atmospheric dispersion model. Another software AERMOD View dispersion model, developed by Lakes Environmental software-a regulatory plume modeling system having three components: AERMOD View(Dispersion Model), AERMAP (AERMOD VIEW Terrain Pre-processor), and AERMET (AERMOD VIEW Meteorological Pre-processor) was also used extensively to estimate pollution concentration and dispersion from numerous sources.

Table 1: Reference Discrete Receptors

Discrete Receptor/ High Volume Air Sampler	Zones	Radial Distance from The Site (Km)	Location UTM Coordinates(X/Y)M
Near mine	Core Zone	0.53	205399/1584949
Tummalapalle		1.17	203872/1585626
Mabbuchintalapalle		2.80	203727/1586740
Rachakuntapalle		3.74	208347/1583430
Bhumaigaripalle		3.93	208903/1585972
Velpula	Buffer Zone-1	4.55	205603/1589744
Besthuvaripalle		6.64	203656/1591584
V. Kothapalle		7.85	215058/1589985
Vemula	Buffer Zone-2	9.90	211076/1590272
JNTU, Pulivendula		14.28	201606/1597635
Pandulakunta		17.70	196705/1569471

TOPOGRAPHY

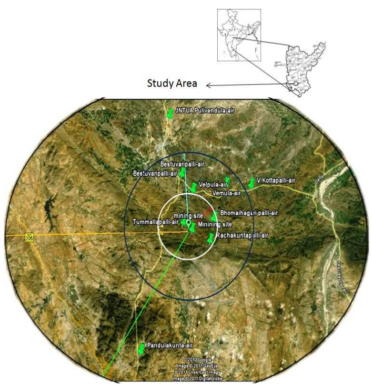

Figure 1: Receptor Locations in the Mine Surroundings

LITERATURE

Atmospheric dispersion modeling refers to the mathematical description of contaminant transport into the

atmosphere. Advances in the development of dispersion models and software made it easier to simulate the transport and transformation of radio nuclides in the atmosphere, its consequences with high degree of accuracy and faster than real time model. Different modeling approaches are used. In Lagrangian model, particles with assigned mass of pollutants move along trajectories determined by the advection field, turbulence and depend on the interpolation of meteorological data [1]. Eulerian models use grid based methods and consider three dimensional descriptions of meteorological fields rather than single trajectories with adaptive gridding method instead of fixed meshes [2]. Simple Gaussian Plume dispersion Model may not give realistic concentrations in typical cases. Modifications to this model were recommended by many researchers [3-6] and ground level concentrations at coastal fumigation were estimated [7, 8] through modified Gaussian plume model. [9] Have studied a point source plume at high altitudes with a modified Gaussian model. The simplicity in input requirement and straight-line nature of the plume are maintained in the modified GPM. [10] Has reviewed the inter-comparison studies of AERMOD VIEW and ADMS, and discussed the output features of these models. [11] Have discussed the regulatory and compliance-based modeling for air quality impact assessment for predicting future air quality under various management scenarios particularly where air quality monitoring data are limited. They have computed the concentration of CO, NOX, SO2 and PM10 at sensitive receptor locations and compared to WHO interim guidelines. The 1-hour, 8-hour and 24-hour averages of monitored PM10, NOx and SO_2 (during 2004-2009 at three observational sites in Delhi) were compared with the Central Pollution Control Board (CPCB) standards by [12] and emphasized the requirement of good emission inventory and advanced modeling approaches for developing emission control programs. The disposal of the tailings within a permanent containment system is an important aspect of the uranium ore processing [13]. A. Murad Basha et.al estimated the combined air quality index in and around our site-Tummalapalle mine located in KADAPA district seasonally [14] and W. R. Reed reviewed different dispersion models for mining operations [15]. Alan J. Cimorelli et.al, gave a detailed report on the minimum data required for modeling through AERMOD VIEW and they noticed single level of on-site data gives higher pollutant concentrations than full on-site data and later one is recommended for better outcomes [16].

Unfortunately there is still a lack of dispersion studies for uranium mining activities and it is important to advance the current understanding of PM10 dispersion. Study of the dispersion and occurrence of the metal and its daughters is therefore required if the environmental impacts of such operations are to be assessed. The main goal of our investigation was to determine statistically the most probable dispersion direction of toxic substances originated from the Tummalapalle Uranium mine. The following equations available in related literature have been used as applicable to our scenario.

MODIFIED GAUSSIAN DISPERSION MODEL

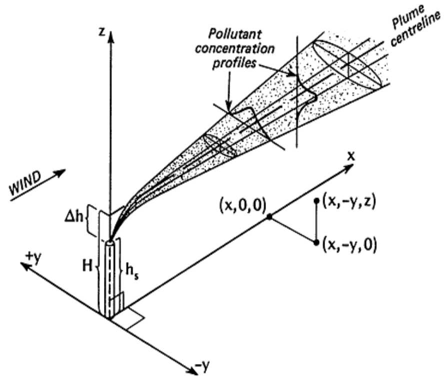

Figure 2: Gaussian Plume Dispersion

GAUSSIAN PLUME EQUATION

$$C = \frac{Q}{2\Pi u \sigma_y \sigma_z} \exp - \left[\frac{y^2}{2\sigma_y{}^2} \right] . \exp - \left[\frac{(z+H)^2}{2\sigma_z{}^2} \right] \quad (1)$$

Where

C: Air pollutant concentration in g/m3

Q = source emission rate in g/s

u= wind speed in m/s

y = crosswind distance from stack of point in m

z = vertical height of point (0 for ground-level concentration)[m]

H =effective stack height in m (includes plume rise)

σy = horizontal stability case parameter (a function of downwind distance x, and stability) [m]

σz = vertical stability case parameter (a function of downwind distance x, and stability) [m]

For Radioactive species like Uranium, Gaussian Plume model can be applied assuming, non reactive species. The equation for the change in concentration of non reactive species (i) with respect to time from constant source is

$$C_{(x,y,z,H)} = \frac{Q}{2\Pi u \sigma_y \sigma_z} \exp\left(\frac{-y^2}{2\sigma_y^2} \right) \left[\exp \frac{-(z-H)^2}{2\sigma_z^2} + \exp \frac{-(z+H)^2}{2\sigma_z^2} \right] \quad (2)$$

The lateral and vertical dispersion coefficient functions $\boldsymbol{\sigma}_y$ and $\boldsymbol{\sigma}_z$ can be obtained using Pasquill-Gifford-Turner estimates shown in the equations below. K_1 to K_5 depend on atmospheric stability classes, for this study K_1=0.202 K_2=370, K_3=0.162, K_4=0.0962, K_5= -0.101[17].

$$\sigma_{s,y} = \frac{K_1 . x}{\left(1 + x / K_2 \right)^{K_3}} \quad (4)$$

$$\sigma_{s,z} = \frac{K_4 . x}{\left(1 + x / K_2 \right)^{K_5}} \quad (5)$$

The Maximum Ground Level Concentration will available at some downwind distance below the centerline of the plume (y = 0, z = 0) then Eq. (1) reduces to

$$\frac{Cu}{Q} = \frac{1}{\sigma_y \sigma_z} exp \left[- \frac{H^2}{2\sigma_z{}^2} \right]$$

For Radioactive substances like Uranium, $$C_{(x,y,z,H)} = \frac{Q}{2\pi u\sigma_y\sigma_z}\exp\left(\frac{y^2}{2\sigma_y^2}\right)\left[\exp\frac{-(z-H)^2}{2\sigma_z^2}+\exp\frac{-(z+H)^2}{2\sigma_z^2}\right]\exp\left(\frac{-k_x}{u}\right) \quad 6$$

METHODOLOGY

MATLAB uses input the parameters of stack height, source emission rate, wind speed, and atmospheric stability, the application creates an collection of downwind ground level plume concentrations were plotted. The MATLAB program was initially run and modified in order to include the simulation of pollutants dispersion from fugitive sources considered as point sources stacks. Simulation runs were carried out. The results were evaluated with measured data and with the predicted results obtained from the AERMOD VIEW) model and excellent agreements were obtained. The influence of meteorological parameters such as wind velocity, ambient temperature, atmospheric stability and surface roughness on pollutants distribution were also discussed. Further, the possible ways and means are suggested for reducing maximum ground level concentrations in addition to pollutants released from mining activities.

CASE STUDY

Sensitivity analysis studies were carried out to get the parameters and best equations which describes the model and contrasted the results with the measured data. Then the the it can solve for different set of input parameters by means of a program for various atmospheric conditions. For the validation of the model,pollutant dispersion on Jan6,2011 was analyzed. The observed values from AERMOD VIEW and MATLAB were compared with the monitored values. PM10 and Uranium concentrations were evaluated.

Annual Wind Rose plot showed in Figure 3obtained from WR Plot view software with the help of pre processed meteorological data for Tummalapalle location. Average annual wind speed for this site was 3.85m/s for the year 2011. In this area solar insolation is strong, hence this area is assumed to have moderately unsteady conditions -B [17].

The Wind rose shows the most pre- dominant wind direction blows from WS, secondary wind direction being from the WWS direction. This means that the emissions plume will be dispersed mainly NE, NEE direction. Calm conditions are observed for 3.28% of the total time. The wind data were further analyzed to obtain predominant wind direction and average wind speed for 0 to 24 hrs and the same data were used in prediction of impacts on air environment.

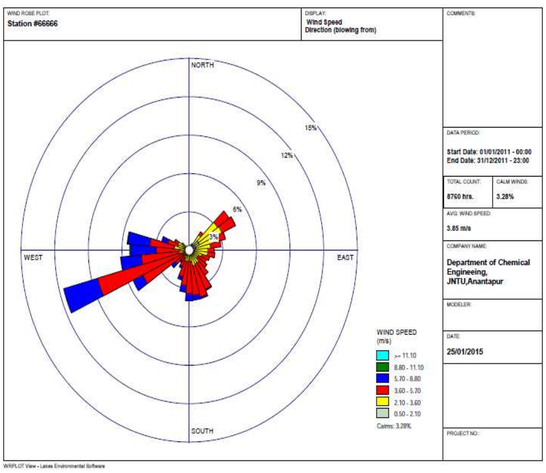

Figure 3: Wind Rose Diagram for Mine Area for 2011

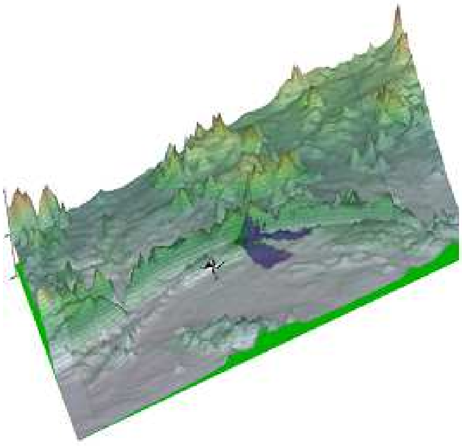

Figure 4: Vertical Exaggerated View of Mine

Table 2: Observed Concentrations through AERMOD, MATLAB and Actual Monitored Values

Discrete Receptor/ High Volume Air Sampler	Location UTM Coordinates (X/Y)M	Distance from Source (km)	AERMODE View PM10 (µg/m3)	AERMODE View Uranium (µg/m3)	MATLAB PM10 (µg/m3)	MATLAB Uranium(µg/m3)	Monitored PM10 (µg/m3)	Monitored Uranium (µg/m3)
Near mine	205399/1584949	0.53	45.8	9.2	35	7	87.1	9.5
Tummalapalle	203872/1585626	1.17	38.5	17.2	51	14	74	23.3
Mabbuchintalapalle	203727/1586740	2.5	22.4	12.1	49	9	Not Monitored	Not Monitored

RESULTS AND DISCUSSIONS

The study was carried out to analyze 24 hour average values for about 10 different locations present around the mine. Table 2 shows average values at mining site, Tummalapalle, and Mabbuchintalapalle and observed the values are well below the standard level.

The modeling pictures (Figures 4 to 11) give pollutant concentration and dispersions at different receptors around mine incorporated on to Google Earth with the actual terrain elevations. Figure 4 gives the MATLAB projected 24 hour maximum value representing direct concentration levels at different locations. The figure5, plotted for Concentration Vs Distance, depicts that observed minimum pollutant concentration was 0.97µg/m^3. For a period of 24h the concentration has increased from 0.97 to 35µg/m^3. The model held good only up to 1.5 km from the source, from there it could not match the monitored value (87.1µg/m^3), it showed very large deviation from the monitored (87.1µg/m^3) and AERMOD VIEW modeled value (45.8µg/m^3). With the AERMOD VIEW Maximum concentration of PM10 was 45.8µg/m3 obtained at (205074, 158601m) in North-West Direction and a maximum concentration of Uranium = 17.2 µg/m3 was obtained at (205024, 158192m) in North-West Direction. The minimum pollutant concentration was less than 0.70 µg/m3 and while for a period of time the concentration has increased from0.70 µg/m3 to17.2 µg/m3. Table 2 summarizes the maximum predicted concentrations for the study area and their comparison with other models. The results revealed that the maximum predicted ground level concentrations from the sources of the mine area did not exceed the Significant Impact Concentrations. Additionally the maximum predicted ground level pollutant concentrations from the mine area sources and the baseline concentrations (as recommended in the Air Quality Guideline Document) were all less than the NAAQS. More concentrations could have been observed in the summer season (especially between mid of April to May) when the dispersion from the mining site would be more dominant towards tummalapalle and Mabbuchintalapalle and

Bsthuvaripalle, because of the dominant atmospheric flow pattern. With two exceptions, the modeled effects on constituent levels in close proximity to the site were shown to fall below air quality standards. One was attributable to the assumption made about the height of the stack and the Ventilation shaft of mine was installed on the ground above 8 m close to the mill complex. This aspect will be investigated further at the next level of design to mitigate any on-site effects of the operation. The other exception was the predicted maximum 24-hour PM10 levels which were shown to exceed the maximum acceptable standard in the vicinity of the Project stock pile site. However, the analysis did not take into account any reduction in dust emissions due to natural causes (i. e wet ground conditions) or operating procedures that can be implemented to reduce dust emissions during adverse weather conditions. Weekly concentrations of U in air varied from the detection limit of0.06µg/m3to 75.7µg/m3 with a geometric mean of 8.05µg/m3. Decreases in concentration during the summer facility slowdown period indicated that the observed levels of airborne U resulted primarily from processing operations, and not from the re suspension of previously emitted material. The committed inhalation dose to the nearest receptor from I year of facility operation was estimated to be 0.014mSv. This was well below ICRP guidelines, and represented a small fraction of normal background radiation. No health effects would be expected at these levels.

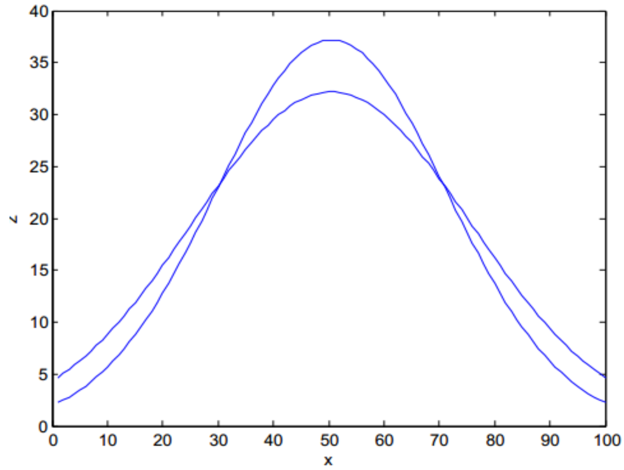

Figure 5: Matlab Graph Receptor Number vs pm10 Concentration

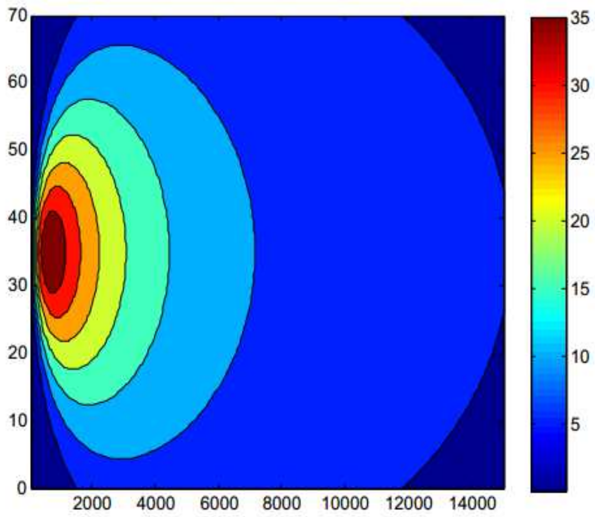

Figure 6: Mat Lab Model Plume Dispersion of PM10

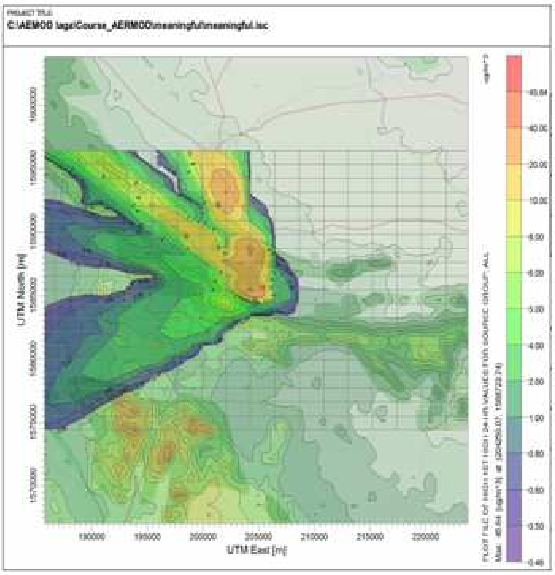

Figure 7: PM 10 Dispersion

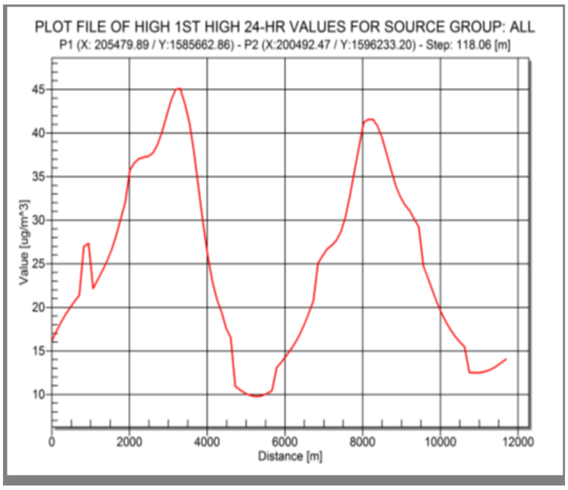

Figure 8: PM10 24 Hour concentration Vs Distance

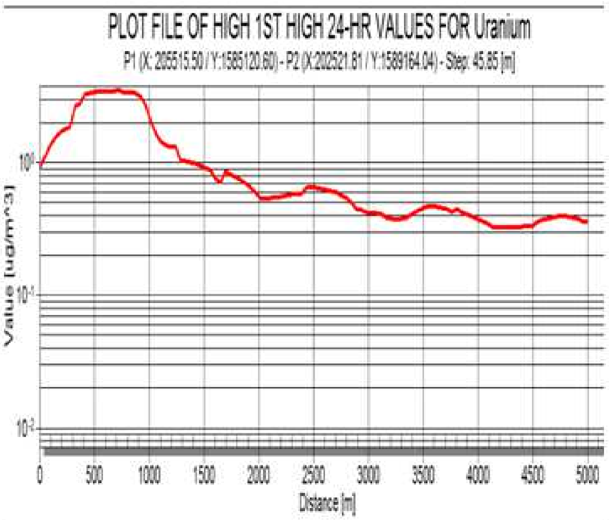

Figure 9: Concentration vs Distance for Uranium

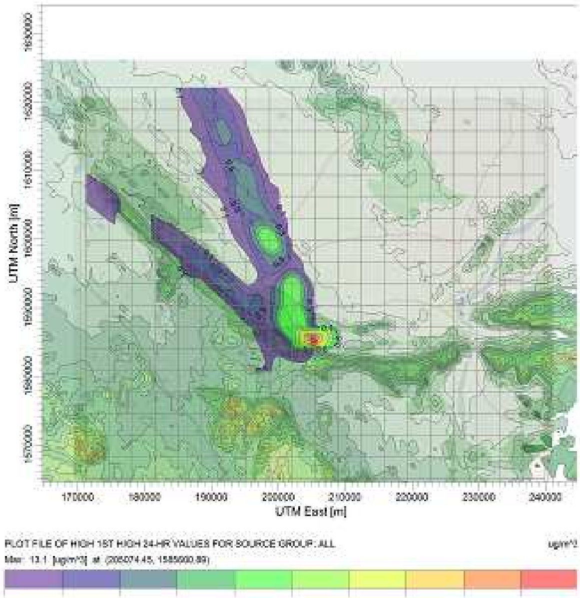

Figure 10: Uranium Dispersion on 06-01-2011

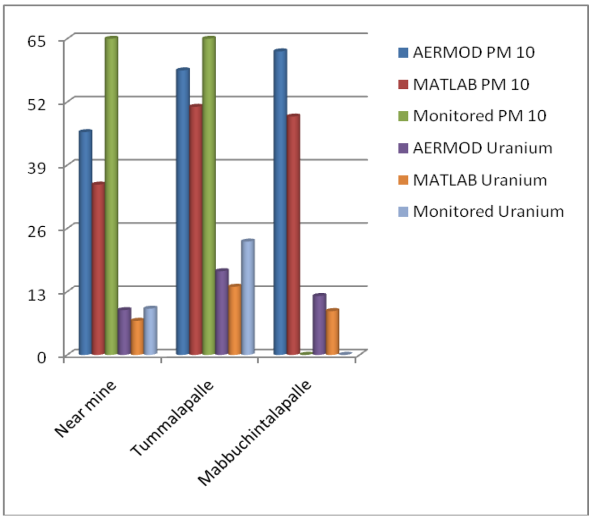

Figure 11: Comparison of PM10, Uranium VALUES

CONCLUSIONS

This work presents the analysis of air pollutants (PM 10 and Uranium) emitted in the form of fugitive dust from Tummalapalle uranium mine related activities. AERMOD VIEW and MATLAB along with site specific pre processed meteorological data were used to estimate the concentrations of air pollutants in the vicinity of the project in order to ensure compliance with the Indian standards (CPCB) for ambient air quality. Observations from this work reveal that during mining with the present plant capacity (2000 TPD), It was noticed that maximum pollutants concentration was obtained near mining site with average and maximum concentrations of 26.8 mg/m3 and 61 mg/m3 respectively for PM10. For 24hr period, pollutants concentration at all receptors placed were found to be within NAAQS limits. From the mine activities, the released pollutants concentrations are not likely to present any considerable adverse impact on the environment in the vicinity of the mining area. Despite of the uncertainties involved, the dispersion model AERMOD view was found to give reasonable results with measured pollutants PM 10, U,) than MATLAB.

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